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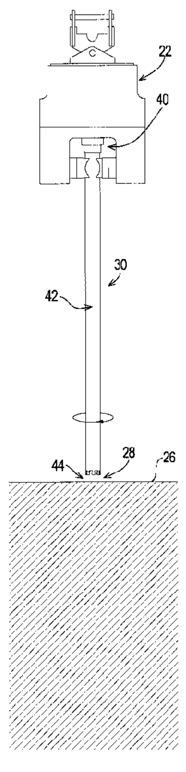
(54) Titre : SYSTEMES ET METHODES D'INSTALLATION DE STRUCTURES DE PIEU DANS LE PERGELISOL
(54) Title: SYSTEMS AND METHODS FOR INSTALLING PILE STRUCTURES IN PERMAFROST



(57) Abrégé/Abstract:
The present invention relates to pile driving systems and method, in particular, to a method for installing pile structures in permafrost ground. The method comprising the steps of rotating a mandrel to form a pilot hole to a pilot hole depth, where friction created by engagement with the mandrel and the permafrost melts liquids in the permafrost, thereby creating a flowable slurry at least partly within the pilot hole; removing the mandrel from the pilot hole; while the slurry is at least partly flowable, arranging at least one pile at least partly within the pilot hole to a pile string depth; and allowing slurry to freeze within the pilot hole at least partly around the at least one pile.

The present invention relates to pile driving systems and method, in particular, to a method for installing pile structures in permafrost ground. The method comprising the steps of rotating a mandrel to form a pilot hole to a pilot hole depth, where friction created by engagement with the mandrel and the permafrost melts liquids in the permafrost, thereby creating a flowable slurry at least partly within the pilot hole; removing the mandrel from the pilot hole; while the slurry is at least partly flowable, arranging at least one pile at least partly within the pilot hole to a pile string depth; and allowing slurry to freeze within the pilot hole at least partly around the at least one pile.

SYSTEMS AND METHODS FOR INSTALLING PILE STRUCTURES IN PERMAFROST

RELATED APPLICATIONS

[0001] This application (Attorney's Ref. No. P2218971ca) claims benefit of U.S. Provisional Application Serial No. 62/266,379 filed December 11, 2015.

TECHNICAL FIELD

[0002] The present invention relates to pile driving systems and methods and, in particular, to systems and methods for installing pile structures in permafrost ground.

BACKGROUND

[0003] In construction projects, the need often exists to support a structure relative to a desired location of the ground. Piles may be used to support the structure relative to the ground. In particular, a predetermined type of pile may be driven into the ground at the desired location to a predetermined pile depth. The type of pile and pile depth are typically predetermined based on conditions such as the nature of the structure (e.g., load) to be supported by the pile and the conditions of the ground at and below the desired location.

[0004] The term "permafrost" is typically used to refer to ground, including rock or soil, at or below the freezing point of water. While many of the techniques employed when driving piles in conventional (e.g., non-frozen) soil may be used in permafrost, the characteristics of permafrost present a unique set of considerations when a pile is to be driven into permafrost.

CA 2950991 2020-10-01

[0005] The need thus exists for pile driving systems and methods optimized for use in permafrost.

SUMMARY

[0006] The present invention is a pile system for permafrost comprising a pilot hole, at least one pile, and frozen slurry. The pilot hole is formed to a pilot hole depth. The at least one pile is arranged at least partly within the pilot hole and extending to a pile string depth. The frozen slurry is within the pilot hole and is at least partly around the at least one pile.

[0007] The present invention is a method of forming a pile system for permafrost comprising the following steps. A mandrel is displaced to form a pilot hole to a pilot hole depth and to create a slurry at least partly within the pilot hole. The mandrel is removed from the pilot hole. While the slurry is at least partly flowable, at least one pile is arranged at least partly within the pilot hole to a pile string depth. Slurry is allowed to freeze within the pilot hole at least partly around the at least one pile.

[0008] The present invention may also be embodied as a method of forming a pile system for permafrost comprising the following steps. A mandrel, a lead pile, and an extension pile are provided. A drive system is operated to rotate the mandrel to form a pilot hole to a pilot hole depth and to create a slurry at least partly within the pilot hole. The mandrel is removed from the pilot hole. While the slurry is at least partly flowable, the drive system is operated to rotate the lead such that the lead pile is arranged at least partly within the pilot hole. The extension pile is connected to the lead pile to form at least part of a pile string. While the slurry is at least partly flowable, the drive system is operated to rotate the extension pile such that the lead pile is arranged within the pile hole

and the extension pile is arranged at least partly within the pilot hole. The slurry is allowed to freeze within the pilot hole at least partly around the lead pile and the extension pile.

[0008A] In a broad aspect, the present invention pertains to a method of forming a pile system for permafrost comprising rotating a mandrel to form a pilot hole depth. Friction is created by engagement with the mandrel and the permafrost melts liquids in the permafrost and creates a flowable slurry at least partly within the pilot hole. The mandrel is removed from the pilot hole and while the slurry is at least partly flowable, at least one pile is arranged at least partly within the pilot hole to a pile string depth. Slurry is allowed to freeze within the pilot hole at least partly around the at least one pile.

[0008B] In a further aspect, the present invention sets out a method of forming a pile system for permafrost by providing a mandrel, providing a lead pile, providing at least one extension pile, and operating a drive system to rotate the mandrel to form a pilot hole to a pilot hole depth. Friction is created by engagement with the mandrel and the permafrost melts liquids in the permafrost, thereby creating a flowable slurry at least partly within the pilot hole, and the mandrel is then removed from the pilot hole. While the slurry is at least partly flowable, the drive system operates to rotate the lead pile such that the lead pile is arranged at least partly within the pilot hole. The at least one extension pile is connected to the lead pile to form at least part of a pile string. While the slurry is at least partly flowable, the drive system operates to rotate the at least one extension pile such that the lead pile is arranged within the pile hole and the at least one extension pile is arranged at least partly within the pilot hole. Slurry is allowed to freeze within the pilot hole at least partly around the lead pile and the at least one extension pile.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] Figure 1 is a side elevation view illustrating a first point in time during a process of installing a pile structure in accordance with the principles of the present invention;

[0010] Figure 2 is a side elevation view illustrating a second point in time during the process of installing a pile structure in accordance with the principles of the present invention;

[0011] Figure 3 is a side elevation view illustrating a third point in time during the process of installing a pile structure in accordance with the principles of the present invention;

[0012] Figure 4 is a side elevation view illustrating a third point in time during the process of installing a pile structure in accordance with the principles of the present invention;

[0013] Figure 5 is a side elevation view illustrating a fourth point in time during the process of installing a pile structure in accordance with the principles of the present invention;

[0014] Figure 6 is a side elevation view illustrating a fourth point in time during the process of installing a pile structure in accordance with the principles of the present invention;

CA 2950991 2020-10-01

[0015] Figure 7 is a side elevation view illustrating a fourth point in time during the process of installing a pile structure in accordance with the principles of the present invention;

[0016] Figure 8 is a side elevation view of a pile structure installed in accordance with the principles of the present invention;

[0017] Figure 9 illustrates a side elevation view of a system that may be used to perform the process of installing a pile structure in accordance with the principles of the present invention;

[0018] Figure 10 is a side elevation view of an example mandrel that may be used by a pile driving system of the present invention;

[0019] Figure 11 is a side elevation view of an example lead pile that may be used by a pile driving system of the present invention; and

[0020] Figure 12 is a side elevation of an example extension pile that may be used by a pile driving system of the present invention.

DETAILED DESCRIPTION

[0021] Figures 1-7 of the drawing illustrate various points during the process of installing an example pile system 20 as depicted in Figure 8. Figures 1-7 also depict a drive system 22 capable of supporting an elongate member and rotating the elongate member that may be used as part of the method of forming the example pile system 20. The example drive system 22 may be, for example, a pile driving system as disclosed in the Applicant's copending U.S. Patent Publication No. 2015/0016893 A1 dated January 15, 2015. As shown in Figure 9, the drive system 22 may be supported by a conventional excavator 24, but any other system capable of supporting a drive system such as the example drive system 22 may be used in place of the excavator. Together, the excavator 24 and drive system 22 allow an elongate member to be driven into the ground 26 at a desired location 28 as will be described in further detail below.

[0022] In Figures 1-3, the drive system 22 is shown rotating an elongate member in the form of a mandrel 30. In Figures 4-7, the drive system 22 is shown rotating an elongate member in the form of a lead pile 32 and one or more extension piles 34. In the example shown in Figures 1-8, only one extension pile 34 is used, but more extension piles may be used depending on the circumstances.

[0023] Figure 10 depicts the example mandrel 30. The example mandrel 30 comprises a drive portion 40, a shaft portion 42, and a bit portion 44. The drive portion 40 is or may be conventional and is adapted to engage the drive system 22 to allow the drive system to axially rotate of the mandrel 30. The example bit portion 44 is formed by a prefabricated insert 46 and made of 4140 steel that houses replaceable teeth 48. The use of the insert 46 with replaceable teeth 48 allows the integrity of the bit portion 44 to be maintained as it is used and provides the ability for rapid rebuild if necessary. Other characteristics of the bit portion 44 will be described below.

[0024] Figure 11 depicts the example lead pile 32. The example lead pile 32 comprises a drive portion 50, a shaft portion 52, and a cutter portion 54. Like the drive portion 40 of the mandrel 30, the drive portion 50 is or may be conventional and is adapted to engage the drive system 22 to allow the drive system to axially rotate of the lead pile 32. The example cutter portion 54 is formed by a Z-cut on the end of the lead pile 32 defining two or more integral cutting teeth 56. The integral cutting teeth 56 provide the lead piles 32 with limited short term cutting ability as will be described below, but without the durability or replaceability of the bit portion 44 of the lead pile 32. Figure 11 further illustrate a trailing threaded portion 58 formed within the lead pile 32 at the upper end adjacent to the drive portion 50. The example trailing threaded portion 58 takes the form of internal threads.

[0025] Figure 12 depicts the example extension piles 34. The example extension pile(s) 34 comprises a drive portion 60, a shaft portion 62, a leading threaded portion 64, and a trailing threaded portion 66. Like the drive portion 40 of the mandrel 30 and the drive portion 50 of the lead pile 32, the drive portion 60 is or may be conventional and is adapted to engage the drive system 22 to allow the drive system to axially rotate of the extension pile 34. The example leading threaded portion 64 is takes the form of external threads on the end of the pile 32. The internally threaded trailing threaded portion 58 of the lead pile 32 receives the externally threaded leading portion 64 of the extension pile 34. If more than one extension pile is used, the internally threaded trailing threaded portion 66 of the first extension pile receives the externally threaded leading portion 64 of the next extension pile 34. In this manner a string of one lead pile 32 and at least one extension pile 34 may be used to form a pile string. Figures 7 and 8 illustrate a pile string 70 comprising a single lead pile 32 and a single extension pile 34.

[0026] Additionally, an internally threaded trailing threaded portion (not shown) may be formed on the mandrel 30. One or more extension piles 34 may be coupled to the mandrel 30 to allow the mandrel 30 to be driven to a depth greater than its length.

[0027] Referring now back to Figure 1-7, the process of forming the example pile system 20 comprising the example pile string 70 will now be described in further detail. Initially, it should be noted that pile string is particularly suited to be used when the ground 26 is formed by what is commonly referred to as permafrost. The ground 26 is thus very cold, and any moisture therein will be frozen.

[0028] The mandrel 30 is coupled to the drive system 22 and axially rotated while suspended above the desired location 28 in the ground 26 as shown in Figure 1. The drive system 22 and mandrel 30 are then lowered or crowded into the ground 26 while the mandrel 30 is axially rotated such that the mandrel 30 penetrates the ground 26 and forms a pilot hole 80 in the ground 26 at the desired location 28 as shown in Figure 2. As the mandrel 30 penetrates the ground 26, the teeth 46 cut into and abrade the dirt and rock of the ground 26 around the pilot hole 80, creating friction.

[0029] The friction created by the teeth 46 heats up the mandrel 30, and the mandrel 30 in turn heats up the ground 26. Liquids in the heated ground 26 melt, creating a slurry 82 within the pilot hole 80. The teeth 46, the material from which the teeth 46 are made, the diameter of the mandrel 30, and speed at which the mandrel 30 is rotated are all controlled such that melted liquids forming at least part of the slurry 82 heat up and expand such that at least a portion of the slurry 82 flows to the surface. Accordingly, at least a portion of the slurry 82 will typically be forced up the pilot hole 80 and form a pool 84 of the slurry 82 on the ground surface where the mandrel enters the ground 26.

[0030] After the mandrel 30 reaches a pilot hole target depth 90 predetermined based on factors such as characteristics of the ground 26 and characteristics of the load (not shown) to be supported by the pile string 70 as shown in Figure 3, the mandrel 30 is removed and detached from the drive system 22. Extensions to the mandrel 30 may be used to allow the example mandrel to reach the pilot hole target depth 90.

[0031] At this point, while the slurry 82 is still melted and at least partly flowable, the lead pile 32 is connected to the drive system 22 and supported above the pilot hole 80 as shown in Figure 4. The drive system 22 and lead pile 32 are then lowered and the lead pile 32 rotated such that the cutter portion 54 of the lead pile 32 enters the pilot hole 80. While the cutter portion 54 of the lead pile 32 does not have the cutting capacity of the bit portion 44 of the mandrel 30, the cutter portion 54 is sufficiently strong and durable to cut through the slurry 82 still in the flowable state. Further, the cutter portion 54 will create friction that will add heat to the slurry 82 as the lead pile 32 is axially rotated while being inserted into the pilot hole 80. The lead pile 32 is inserted to a depth at which the drive portion 50 thereof is still accessible as shown in Figure 5, after which the drive system 22 is disconnected from the lead pile 32.

[0032] Again, while the slurry 82 is still melted and flowable, the extension pile 34 is connected to the drive system 22. The extension pile 34 is supported above the pilot hole 80 as shown in Figure 6 and then rotated such that the threaded portion 58 on the lead pile 32 receives the threaded portion 64 on the extension pile 34 to connect the extension pile 34 to the lead pile 32 to form the pile string 70. The drive system 22 and pile string 70 are then lowered and the pile string 70 axially rotated such that the cutter portion 54 of the lead pile 32 continues through the slurry 82 within the pilot hole 80. Again, the cutter portion

54 is sufficiently strong and durable to cut through the slurry 82 still in the flowable state and will create friction that will add heat to the slurry 83 as the pile string 70 is axially rotated while being inserted into the pilot hole 80. Further, the cutter portion 54 of the lead pile 32 is sufficiently strong to penetrate beyond the pilot hole depth 90 as shown in Figure 7.

[0033] Accordingly, additional rotation of the pile string 70 will continue to cut into the ground 26 beyond the pilot hole depth 90. When the drill string 70 reaches a target drill string depth 92 that is below the pilot hole depth 90 as shown in Figure 7, the rotational and crowding forces are no longer applied to the drill string 70. Again, the target drill string depth 92, and possibly the distance between the pilot hole depth and the target string depth 92, will typically be predetermined based on requirements of the load and characteristic (e.g., soil conditions) of the ground 26 at the desired location 28. The drive system 22 is then removed from the drill string 70, and the slurry 82 is allowed to refreeze, securing the pile string 70 in a desired orientation at the desired location 28 as shown in Figures 8.

[0034] When the pile string 70 is secured in the desired orientation at the desired location 28 as shown in Figure 8, the example pile system 20 is formed by the pile string 70, the ground 26 around the pile string 70, and the frozen slurry 82 adjacent to the pile string 70. At this point, a structure or load may be supported by the pile string 70 in a conventional manner. The Applicant's U.S. Publication 2016/0356294 A1 dated December 8, 2016 discloses Systems and Methods for Connecting a Structural Member to a Pile that may be used on the uppermost extension pile 34 of the pile string 70 depicted in Figure 8. However, other systems and methods may be used to secure a structure to the pile string 70.

[0035] In this specification, the use of a letter suffix with any reference character does not necessarily indicate that an element generically identified by that reference character is different from an element specifically identified by the reference character with a letter suffix. Accordingly, any reference character used without a letter suffix in the specification may generally refer to the same reference character used with a letter suffix in the drawing.

What is claimed is:

1. A method of forming a pile system for permafrost comprising the steps of:

rotating a mandrel to form a pilot hole to a pilot hole depth, where friction created by engagement with the mandrel and the permafrost melts liquids in the permafrost, thereby creating a flowable slurry at least partly within the pilot hole;

removing the mandrel from the pilot hole;

while the slurry is at least partly flowable, arranging at least one pile at least partly within the pilot hole to a pile string depth; and

allowing slurry to freeze within the pilot hole at least partly around the at least one pile.

2. The method as recited in claim 1, in which the at least one pile comprises a lead pile.

3. The method as recited in claim 1, in which the at least one pile comprises an extension pile.

4. The method as recited in claim 1, in which the step of arranging the at least one pile at least partly within the pilot hole comprises the steps of:

providing a plurality of piles; and

forming a pile string comprising the plurality of piles.

5. The method as recited in claim 4, in which the step of providing a plurality of piles comprises the step of providing a lead pile and at least one extension pile.

6. The method as recited in claim 4, in which the step of forming the pile string further comprises the steps of:

arranging the lead pile at least partly within the pilot hole;

connecting a first extension pile to the lead pile to form at least part of the pile string; and

displacing the at least part of the pile string formed by the lead pile and the first extension pile such that the first extension pile is arranged at least partly within the pilot hole.

7. The method as recited in claim 6, in which the step of forming the pile string further comprises the steps of:

connecting a second extension pile to the first extension pile to form at least part of the pile string; and

displacing the at least part of the pile string formed by the lead pile and the first and second extension piles such that the second extension pile is arranged at least partly within the pilot hole.

8. The method as recited in claim 1, in which the pile string depth extends beyond the pilot hole depth.

9. The method as recited in claim 1, further comprising the step of predetermining the pile string depth based on at least one of:

ground characteristics at a desired location at which the pilot hole is to be formed; and

a load to be supported by the pile string after the slurry has been allowed to freeze.

10. A method of forming a pile system for permafrost comprising the steps of:

providing a mandrel;

providing a lead pile; providing at least one extension pile;

operating a drive system to rotate the mandrel to form a pilot hole to a pilot hole depth, where friction created by engagement with the mandrel and the permafrost melts liquids in the permafrost, thereby creating a flowable slurry at least partly within the pilot hole;

removing the mandrel from the pilot hole;

while the slurry is at least partly flowable, operating the drive system to rotate the lead pile such that the lead pile is arranged at least partly within the pilot hole;

connecting the at least one extension pile to the lead pile to form at least part of a pile string;

while the slurry is at least partly flowable, operating the drive system to rotate the at least one extension pile such that the lead pile is arranged within the pile hole and the at least one extension pile is arranged at least partly within the pilot hole; and

allowing slurry to freeze within the pilot hole at least partly around the lead pile and the at least one extension pile.

11. The method as recited in claim 10, in which the step of arranging the lead pile and the at least one extension pile at least partly within the pilot hole comprises the steps of:

providing a plurality of extension piles; and

forming the pile string by connecting one of the plurality of extension piles to the lead pile and one of the plurality of extension pile to the extension pile connected to the lead pile.

12. The method as recited in claim 11, further comprising the step of rotating at least a portion of the pile string such that the pile string extends to a pile string depth.

13. The method as recited in claim 12, in which the pile string depth extends beyond the pilot hole depth.

14. The method as recited in claim 12, further comprising the step of predetermining the pile string depth based on at least one of:

ground characteristics at a desired location at which the pilot hole is to be formed; and

a load to be supported by the pile string after the slurry has been allowed to freeze.

FIG. 1

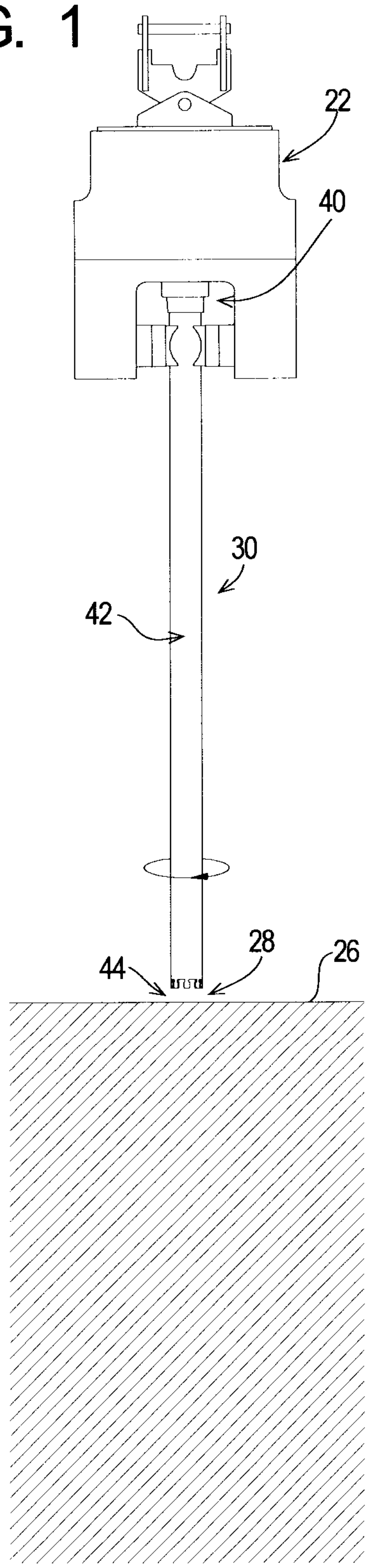


FIG. 2

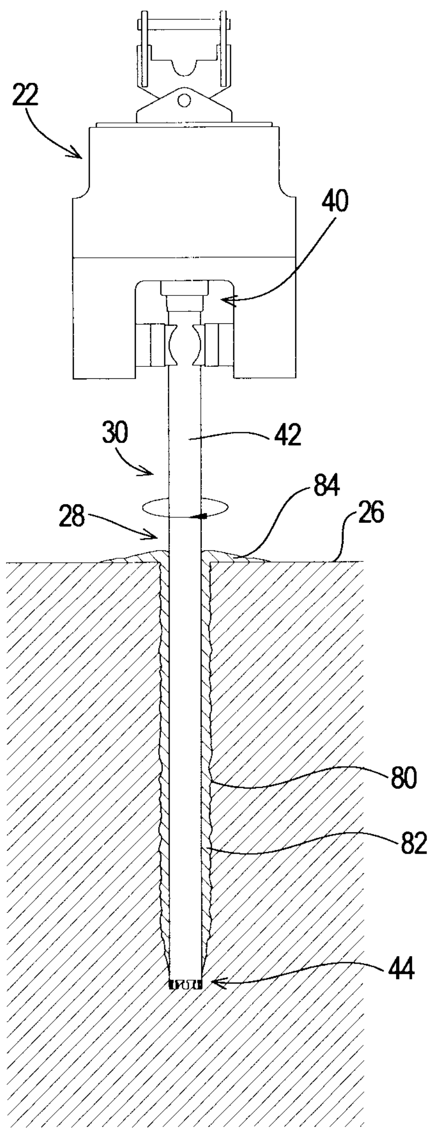
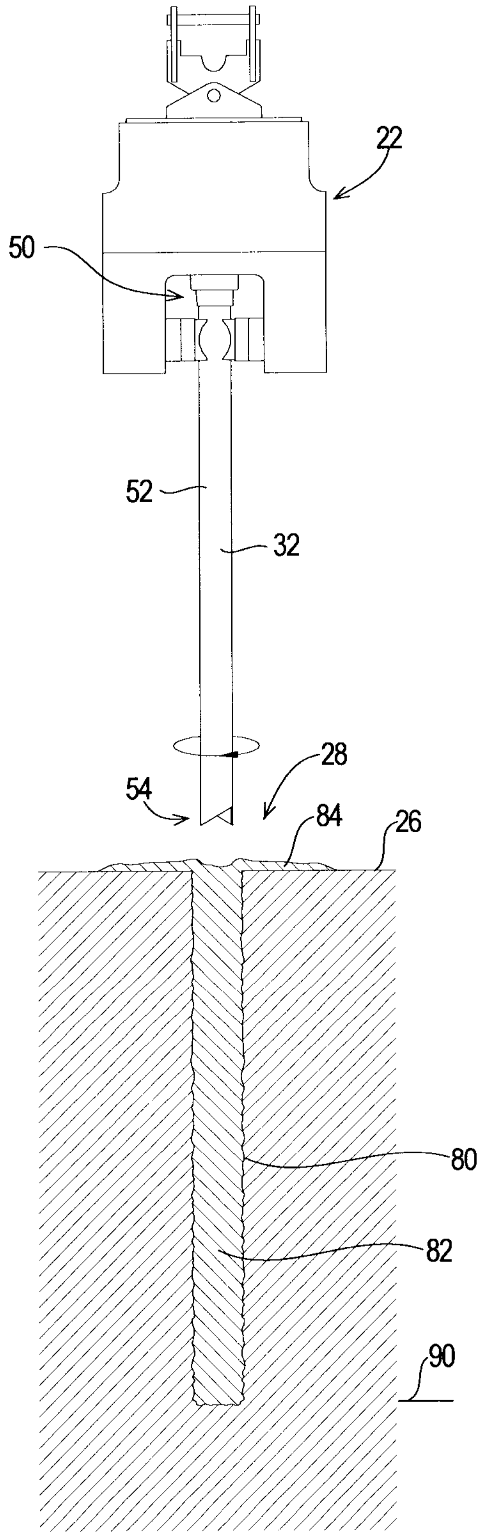


FIG. 4



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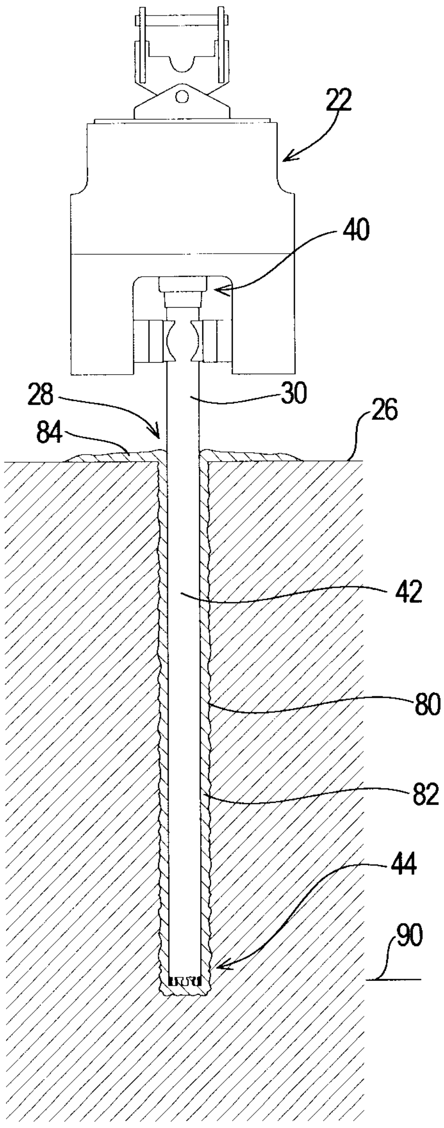

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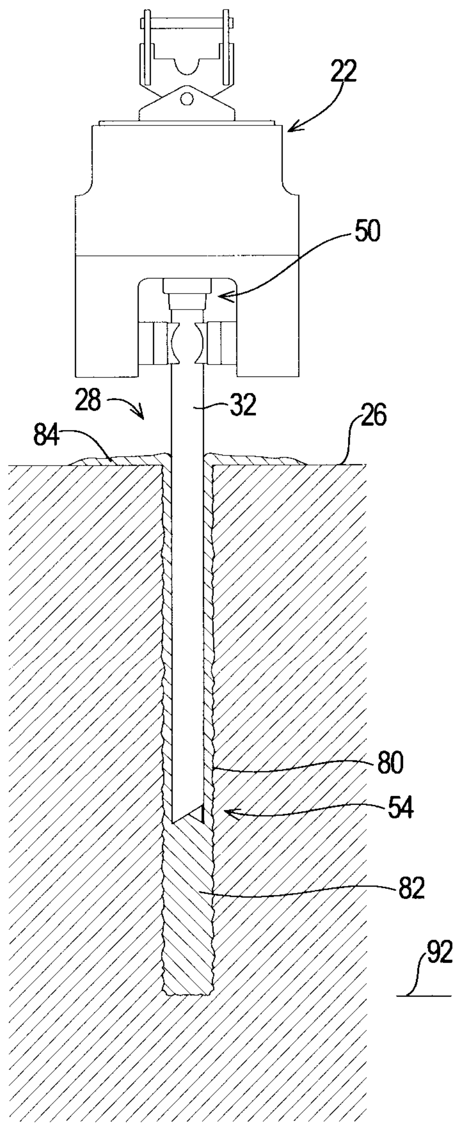

FIG. 6

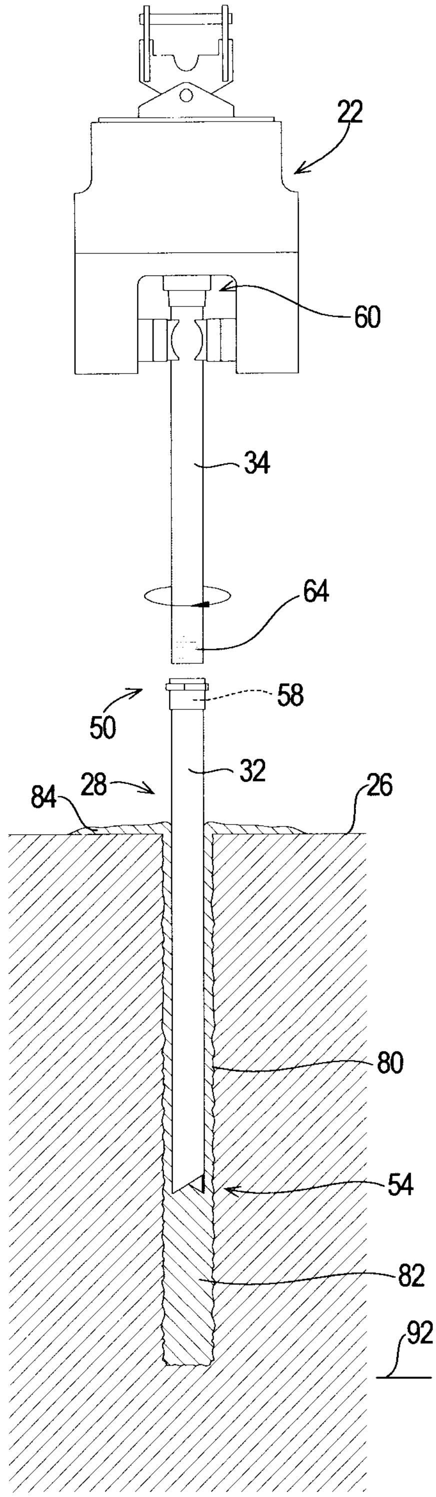

FIG. 7

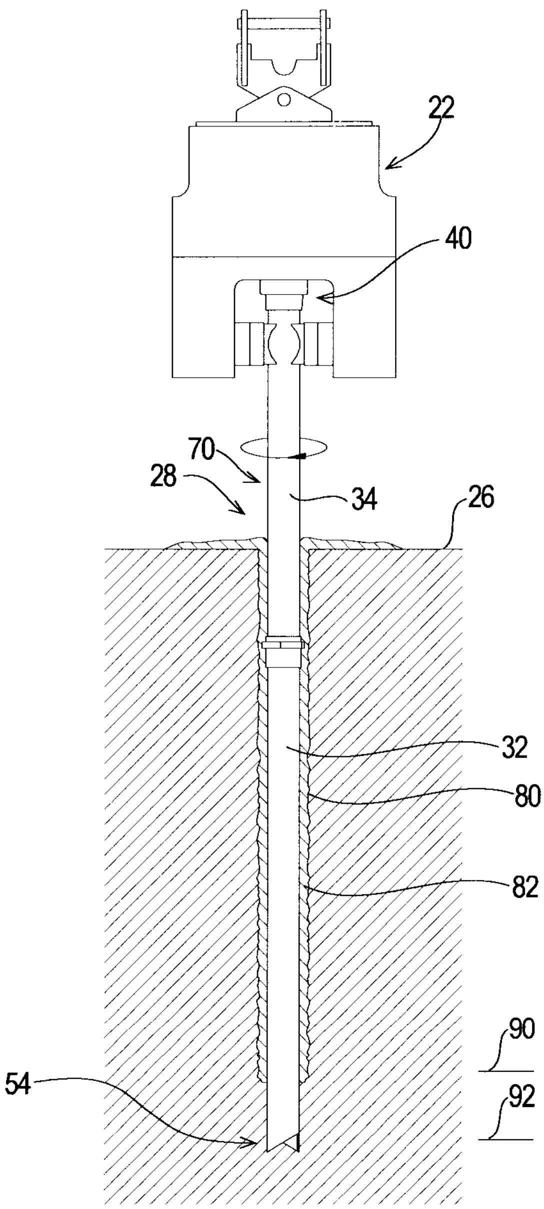
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FIG. 8

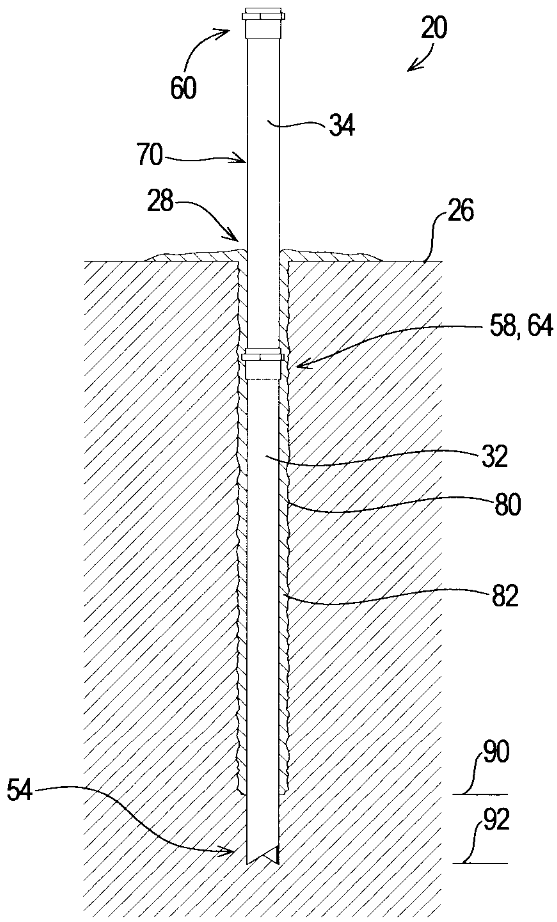
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FIG. 9

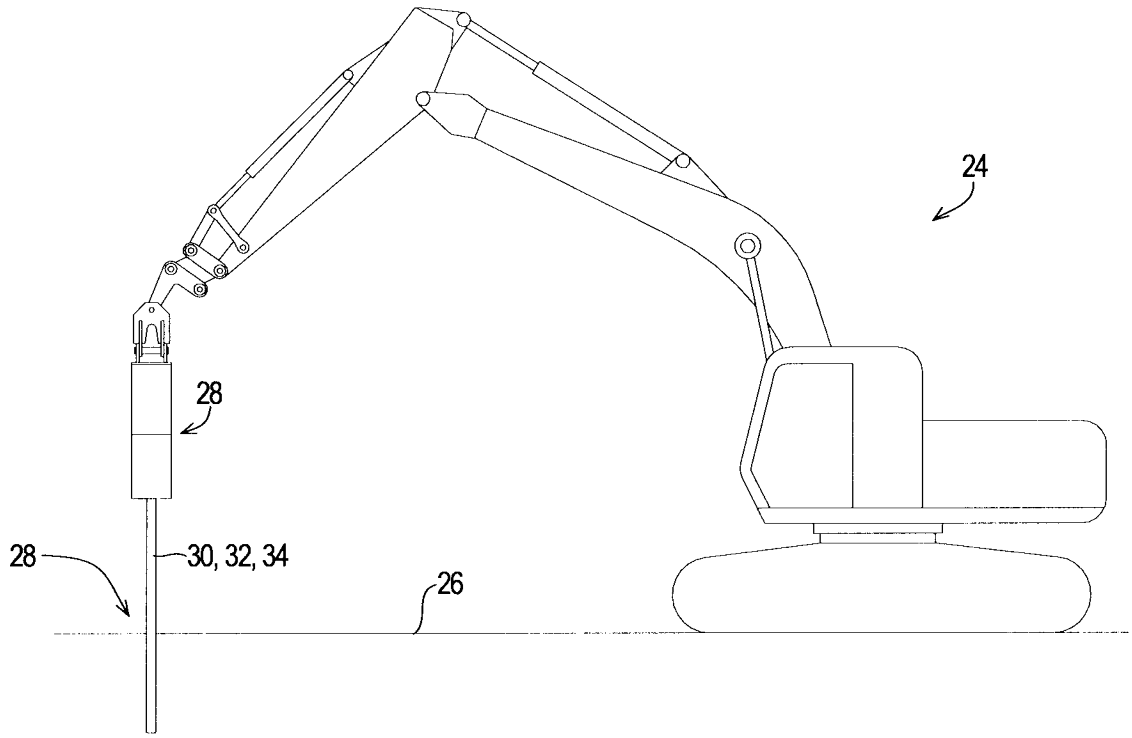

FIG. 10

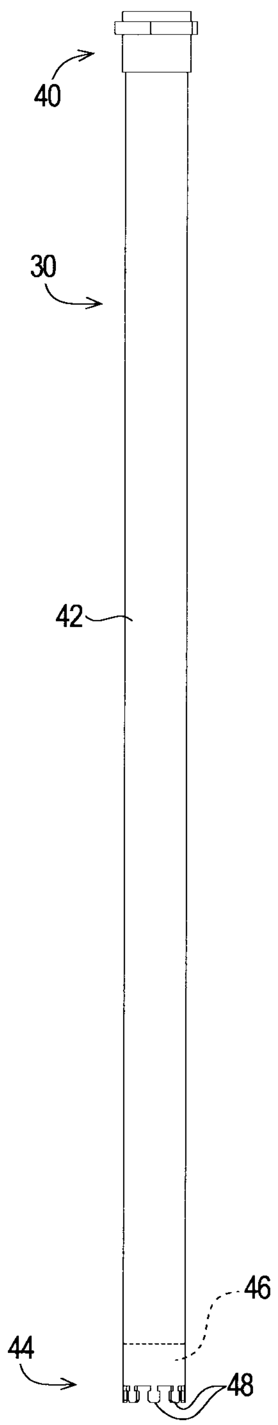

FIG. 11

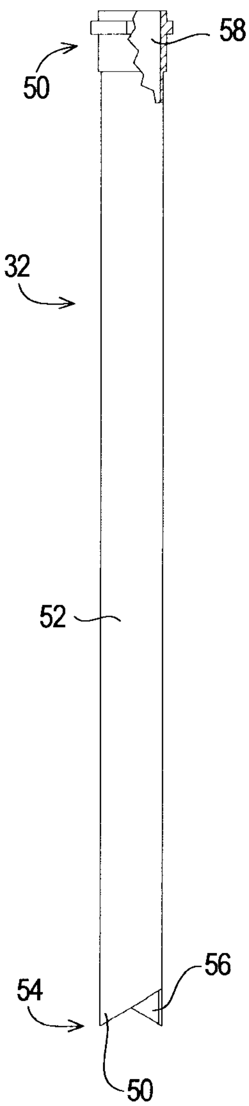

FIG. 12